PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in and relating to High Vacuum Pumps

We, BALZERS PATENT- UND BETEILIGUNGS AKTIENGESELLSCHAFT, a body corporate organised under the Laws of the Principality of Liechtenstein, of Balzers, Principality of Liechtenstein, formerly named Balzers Patent- und Lizenz-Anstalt, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to high vacuum pumps.

For the production of very high vacua of 10^{-8} mmHg and below nowadays diffusion pumps with cooled baffles are used, or ion getter pumps as well as cryo pumps. When, as in thermo-nuclear fusion experiments, high pumping speeds are to be applied to very large receptacles, diffusion pumps are in general insufficient, since as well known they pump the gas particles at a velocity, which is substantially one order of magnitude smaller than the thermal molecular velocity. Moreover, efficient baffles considerably reduce the effective pumping speed. Ion getter pumps comprise two electrodes lying at a high potential of 1—5 kV, relative to each other between which there is a gas discharge, which ionises the gas to be pumped. By means of a suitably directed external magnetic field, the electrons contained in the gas discharge move over a larger mean free path, whereby a higher yield of ionisation is attained. The cathode usually consists of a highly effective getter metal such as zirconium, molybdenum or titanium, which is evaporated by the impact of positive ions accelerated by the electric field, whereby getter material is deposited on the anode and there sorbs large amounts of the non-ionised gas. The getter effect is, however, limited to chemically active gases; inactive or noble gases are occluded into the cathode by ionisation only and thus pumped off. Ion getter pumps can be used only in combination with other pumping methods, generally with diffusion pumps, since the active getter surface has to be produced at very low pressures.

Cryo pumps have condensation surfaces, which are kept at very low temperatures. Their action is based on the fact that the gas molecules impinging these condensation surfaces are retained there with a certain probability, and condensed as a continuous layer. The lowest pressures attainable by this method depend on the partial pressure of the gas component pumped at the temperature prevailing on the condensation surface. With a condensation surface cooled to the temperature of liquid helium, nitrogen can be pumped off at a vacuum of about 10^{-11} mmHg. However, for hydrogen, which is used for the aforesaid thermonuclear fusion experiments, the sticking coefficient at 4.2°K is still very small; in order to be able to pump off this gas effectively, the helium bath of the condensation surface has to be cooled down to at least 2.5°K by pumping off. Obviously, helium cannot be pumped off from a receptacle at all by this method.

The present invention obviates the disadvantages of the aforesaid known pumping methods which manifest themselves particularly at ultra-high vacua, and is equally suitable for the generation of a very high vacuum with chemically active as well as inactive and noble gases.

A high vacuum pump according to the present invention comprises at least two electrodes, between which a high potential difference is maintained in operation, and a superconductive coil generating simultaneously a magnetic field, whereby in the gas to be pumped off an electrical gas discharge is maintained; a cathode consisting of getter material, which is partly vaporised by the impact of gas ions, the vaporised getter material being deposited on the anode, so that the gas to be pumped off is sorbed by

[Price 4s. 6d.]

gettering action as well as by the capturing of ions on the two electrodes; and comprising cooling means for cooling in operation at least one of the said two electrodes to a temperature below 20°K.

The great advantage attained thereby consists in that such a pump acts as a cryo pump even without the application of potential difference, and generates a vacuum of 10^{-7} mmHg in relation to nitrogen or oxygen. When thereafter the ion getter pump is set in operation and a weak gas discharge is kept up at a high voltage material of the cathode, which consists of titanium or zirconium, is evaporated and is deposited on the anode. This metal deposit acts as an effective getter for chemically active gases such as nitrogen, oxygen, carbon dioxide, carbon monoxide, water vapour whose probability of adhesion (sticking coefficient) suffices at room temperature for pumping off these gases, and the effectiveness of which increases considerably at very low temperatures and suffices even for pumping off hydrogen. The said gas discharge has the effect that noble gases are ionised and removed by the ions being caught at the cathode. Likewise, the pumping effect by the catching of ions is considerably increased by cooling the cathode to very low temperatures. It is known that the getter effect depends largely on the structure of the metal film deposited on the anode, and that it is particularly high, when the same is amorphous or of atomic roughness. The cooling of the anode or of both electrodes to very low temperatures according to the present invention extraordinarily favours the formation of such amorphous or atomically rough layers and thus considerably reinforces the pumping effect of the getter material.

A further important feature of the invention consists in that the bath of very low temperature is used at the same time for producing the magnetic field required for an efficient ion getter pump. So-called hard super-conductors have been known to be available for this purpose i.e. metal alloys and compounds, such as Nb-Zr, Nb-Ti or Nb_3Sn, which are super-conductive even with very strong magnetic fields of 50—150 kG and have moreover a high transition temperature between 10° and 18°K. According to the invention the existing cooling bath of e.g. liquid helium is used for cooling an iron-free magnet coil of super-conductive wire and thus to generate a strong magnetic field in the space between the electrodes of the ion getter pump without a high Ohmic resistance loss. It is moreover known, that the pumping effect of such pumps increases strongly with increasing strength of the magnetic field, since the probability of ionisation increases almost proportionally to the strength of the magnetic field. Already with the present state of knowledge it is not difficult to maintain in a ion getter pump with the aid of super-conductive coils magnetic fields of 10,000 to 20,000 Gauss, and thus to attain greatly increased pumping effects. Super-conductive coils may be likewise used for magnets having iron armatures. For maintaining these magnetic fields current has to be supplied only for building up the magnetic field; by means of a super-conductive shunt a permanent current can be generated in the magnet coil by a method known *per se*, which does not require any external supply of current.

When both electrodes of an ion getter pump are brought to very low temperatures, the effects of the cryo pump, i.e. the condensation of gas as solid layers, are superimposed to those of catching ions and deposition of the getter material, which is deposited in fine dispersion and exerts an efficient getter effect.

The invention will now be explained with reference to the accompanying drawings, in which:—

Figs. 1*a*, 1*b* and 2*a*, 2*b* show in sectional elevation and plan view (section on line A—A) respectively, ion getter pumps with a cooled anode, which is constructed as a closed cooling bath and contains a super-conductive coil for the generation of a strong magnetic field.

Figs. 3*a*, 3*b* show likewise a similar pump, which, however, has a multiple anode vessel and a system of radiation screen baffles surrounding the pump arrangement.

Fig. 4 shows in sectional elevation a cylindrical symmetrical construction of a pump according to the invention, wherein an external super-conductive magnet coil generates an axial magnetic field, and the internal cathode may be optionally cooled in order to reinforce the catching of ions.

Figs. 5*a*, 5*b* and 5*c* show in sectional elevation on the line A—A, in sectional plan view and sectional elevation on the line B—B, respectively, a pump arrangement with a central cylindrical cooling vessel for liquid helium which has radial hollow ribs for the accommodation of super-conductive flat coils generating a circular magnetic field which everywhere is of uniform direction over the entire circumference of the said cooling vessel.

The high vacuum pump illustrated in Figs. 1*a*, 1*b* comprises a pump vessel 1, which by means of a neck 2 extends through the wall 3 of the high vacuum apparatus into the latter. The pump vessel 1, whose external wall together with the annular discs 4 attached thereon forms the anode of an ion getter pump, is surrounded by getter material in the form of sheets 5 of titanium, molybdenum or zirconium. The anode consists of non-magnetisable material e.g. of V2A- steel and is supported freely in the receptacle by the thin-walled tube 2. On the other hand, the cathode metal sheets are carried by the leads 6 and 7 serving for the supply of voltage and passing through the wall of the receptacle, and

allow the applying of a high direct voltage between them and the earthed pump vessel 1. Within the pump vessel 1 there is arranged a magnet coil 8 of superconductive wire or strip, which can be connected with an external current source by means of supply conductors 9 and 10 passing out of the tube 2.

After filling in the cooling liquid, preferably liquid which is of a temperature below 20°K, in a short while a high vacuum of about 10^{-8} mmHg is generated in the receptacle. When subsequently a high direct voltage is applied between the cathode 5 and the earthed pump vessel with the anodes 4 attached to it, and at the same time the magnet coil 8 is excited, a gas discharge takes place between the said two electrodes, which owing to the strong magnetic field generated by the magnet coil is not extinguished even at very low pressures. The positive ions generated by electron impact impinge the sheets consisting of getter material and evaporate getter material from the surface thereof. The same is deposited on the cold anode, and the active metal film thus formed, which is of a high atomic disorder, absorbs to a great extent the gas to be pumped off. Ionised atoms of noble gases are likewise caught under the influence of the high electric field strength of the cathode surface, and are thus removed. By additional cooling of the getter sheet metal this latter effect may be further reinforced. Fig. 1*b* shows in a section on the line A—A of Fig. 1*a* how the cathode may be conveniently subdivided into separate cells by means of transverse ribs, in order to increase the effective area.

A further embodiment of the invention is illustrated by way of example in Figs. 2*a*, 2*b*. In this embodiment the stray field of a short super-conductive cryo coil 11 outside the latter is used in order to increase strongly the probability of impact of the electrons in the gas discharge taking place between the anode 12 and the cathode 13. For this purpose a super-conductive coil 11 is arranged in a container, preferably of cylindrical shape, whose outer wall forms the said anode and which is filled with liquid helium and is attached to the wall 16 of the receptacle to be evacuated by means of a thin-walled metal tube 15 of a material of low thermal conductivity which serves for filling the container. For the purpose of increasing the strength of the stray magnetic field of the cryo coil 11 suitably shaped round screening baffles 17, which consist of a super-conductive material having a high critical field strength such as e.g. Nb-Zr or Nb-Ti alloys, are arranged on the lid and bottom of the helium container. By the thermal contact of these baffles with the helium bath the same are kept in a super-conductive state. they prevent the penetration of a magnetic flux into their interior and thus concentrate the stray flux in the region between the anode 12 and the cathode 13, which is particularly effective for the gas discharge. The cathode 13 consists as in the previously described embodiment of a getter metal, such as e.g. titanium or molybdenum, and has the shape of radially positioned individual sheet metal plates, which offer little resistance to the flow of the gas to be evacuated and which, on the other hand, prevent getter atoms liberated by electron impact from flying outward. The same are intended to be deposited on the anode 12, which is constructed as a tubular piece of V2A-steel or another likewise suitable material, and which is attached to the outer container wall. The getter effect of this continuously renewing surface is strongly increased according to the invention by the effect of the very low temperature at which the anode is kept. The cathode 13, which is provided with a great number of ribs, is arranged concentrically around the anode 12, and a comparatively high negative potential relative to the earthed anode is applied to it.

Yet another embodiment is illustrated in Figs. 3*a*, 3*b* wherein the arrangement is likewise built up around a central cooling vessel connected electrically as an anode. However, the latter consists of three partial vessels 21, 22 and 23 which are connected with one another as shown in the drawing. In each of the vessels 21, 22 and 23 a separate cryo coil 24, 25, 26, respectively, is arranged. The cathodes 27 and 28 are arranged in the spaces between the anodes and are supplied with a high negative potential by a supply conductor 29. The arrangement as a whole is surrounded by angularly turned-up radiation screen baffles 30, which allow the passage of the gas to be pumped, but screen off any direct heat irradiation. When charging the anode containers with liquid helium it is advisable to provide cooling of the irradiation screen baffles with liquid air or to keep the same on an intermediate temperature by thermal contact with the holders of the deep-cooled anode containers. The pump described is carried by a flange 31 by means of which it can be attached to an aperture of the receptacle in such a manner that it projects into the latter. Fig. 3*b* shows a section on the line A—A of Fig. 3*a* and shows particularly the construction of the cathode.

A cylindrically symmetrical embodiment is illustrated in Fig. 4. On the cylindrical pump body 41 a cylindrical cathode 42 is attached electrically insulated, which is surrounded outside by getter metal in the form of a sheet metal shell 43. The anode consists in an annular container 44 of non-magnetisable material, which is held thermally insulated by two thin-walled tubes 45 and 46 on the lid of the pump vessel, which tubes serve at the same time for the charging with liquid helium and for outwardly venting the vapours. In the annular vessel 44 there is arranged a magnet

coil 47 of super-conductive material, whose current supply conductors pass through the charging tubes. By the aid of a flange, the pump is connected with the receptacle to be evacuated. The system comprising the annular anode and central cathode may alternatively be built directly into the receptacle, without a pump vessel 41.

The functioning of this pump corresponds completely to that of the arrangement illustrated in Figs. 1*a*, 1*b*.

Yet another embodiment of the invention is illustrated by way of example in Figs. 5*a*, 5*b* and 5*c*. In this embodiment the pump is likewise designed for being built into the receptacle. The central cylindrical pump vessel made of non-magnetisable material has a plurality of radial hollow ribs 51—56 and is centrally attached on the cover flange 59 of the pump by means of a thin-walled tube 58 of a material of low thermal conductivity. In the interior of the hollow ribs flat coils 60—65 of super-conductive wire are accommodated, the current supply leads of which are passed insulated outward through the holder tube. When energised by a current, these flat coils generate a strong circular magnetic field, which may amount to 5—14 kG when using hard super-conductors; the central vessel and the hollow ribs connected therewith are filled in operation with liquid helium, whose vapour can be vented outwardly through the tube 58. The ribs 51—56 constitute the anode of an ion getter pump. For a cathode, sheet metal pieces 66 of a suitable getter material are used such as e.g. zirconium, molybdenum or titanium, which are supported by the voltage supply conductors 67. The latter are passed electrically insulated through the lid 59; the pump body proper with the ribs, that contain the coils, is earthed.

This construction is so laid out, that the gases to be pumped off from the receptacle can reach the cooling ribs, without appreciable resistance to flow or frictional losses at the walls, where they are condensed in solid form owing to the very low temperature. Owing to the high direct voltage between the anode and the cathode a weak gas discharge takes place between the said electrodes, and getter metal of the cathode is evaporated and condenses on the deep-cooled hollow ribs, where it forms an active getter film. This film is structurally greatly disturbed owing to the very low temperature of the substratum, and possesses excellent sorption properties for the gas to be pumped off. As in the previous embodiments a permanent current may be energised for the creation of a magnetic field, which does not require any external current supply.

For reducing the incoming radiation, moreover a baffle may be arranged as in Figs. 3*a*, 3*b*, which surrounds the entire pump arrangement and may be kept at an intermediate temperature by thermal contact with the holder tube 58.

WHAT WE CLAIM IS:—

1. A high vacuum pump comprising at least two electrodes, between which a high potential difference is maintained in operation, and a super conductive coil generating simultaneously a magnetic field, whereby in the gas to be pumped off an electrical gas discharge is maintained; a cathode consisting of getter material which is partly vaporised by the impact of gas ions, the vaporised getter material being deposited on the anode, so that the gas to be pumped off is sorbed by gettering action as well as by the capturing of ions on the two electrodes; and comprising cooling means for cooling in operation at least one of the said two electrodes to a temperature below 20°K.

2. A high vacuum pump according to claim 1, wherein the said cooling means is used at the same time for the cooling of a super-conductive magnet coil.

3. A high vacuum pump according to claim 2, wherein after energising the super-conductive magnet coil through a super-conductive shunt a permanent current is maintained without external current supply throughout the pumping operation.

4. A high vacuum pump according to claim 1, wherein the cooling means for cooling the super-conductive magnet coil is itself constructed as one of the electrodes between which there is the high voltage potential.

5. A high vacuum pump according to claim 1, wherein the electrodes are of cylindrical shape and the said super-conductive magnet coil generates an axial magnetic field between the two electrodes.

6. A high vacuum pump according to claim 1, wherein the said cooling means is cylindrical and has radial hollow ribs each for accommodating a flat super-conductive coil, which coils when energised produce an azimuthal magnetic field directed over the whole circumference of said cooling means in the same direction, a counter-electrode being arranged between any two of these hollow ribs.

7. A high vacuum pump according to claim 1, substantially as herein described with reference to Figs. 1*a*, 1*b* of the accompanying drawings.

8. A high vacuum pump according to claim 1, substantially as herein described with reference to Figs. 2*a*, 2*b* of the accompanying drawings.

9. A high vacuum pump according to claim 1, substantially as herein described with reference to Figs. 3*a*, 3*b* of the accompanying drawings.

10. A high vacuum pump according to claim 1, substantially as herein described with reference to Fig. 4 of the accompanying drawings.

11. A high vacuum pump according to claim 1, substantially as herein described with reference to Figs. 5a, 5b, 5c, of the accompanying drawings.

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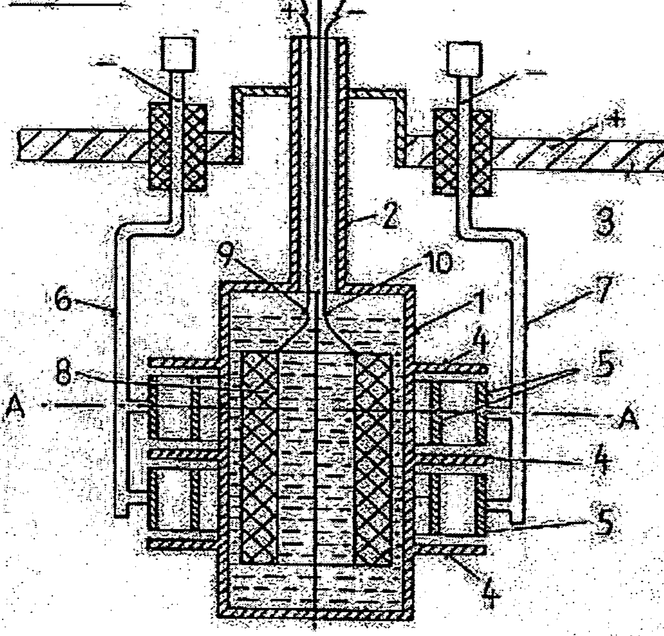
Fig. 1a



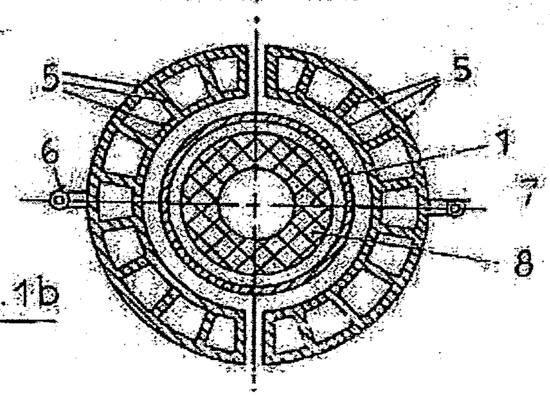
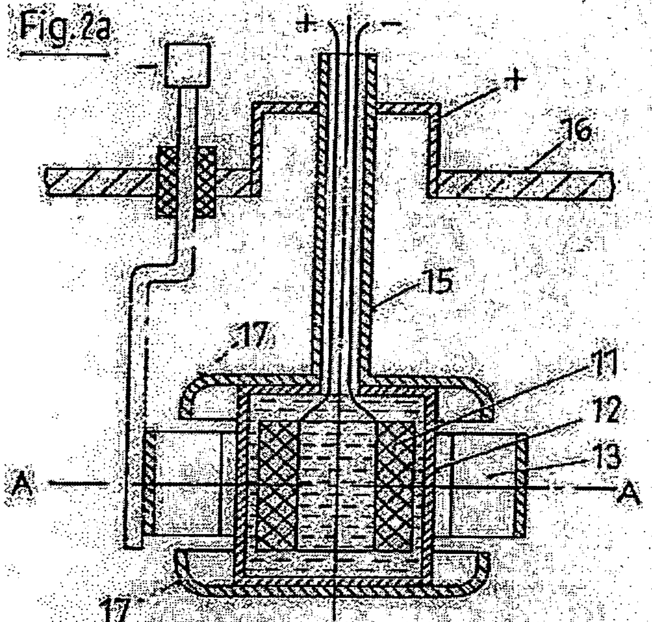


Fig. 1b

Fig. 2a



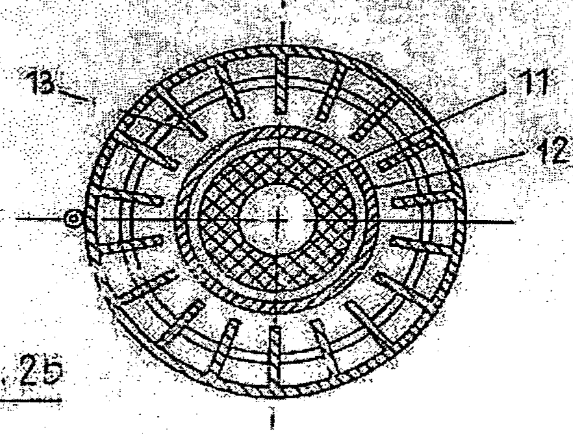


Fig. 2b

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6 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheets 1 & 2

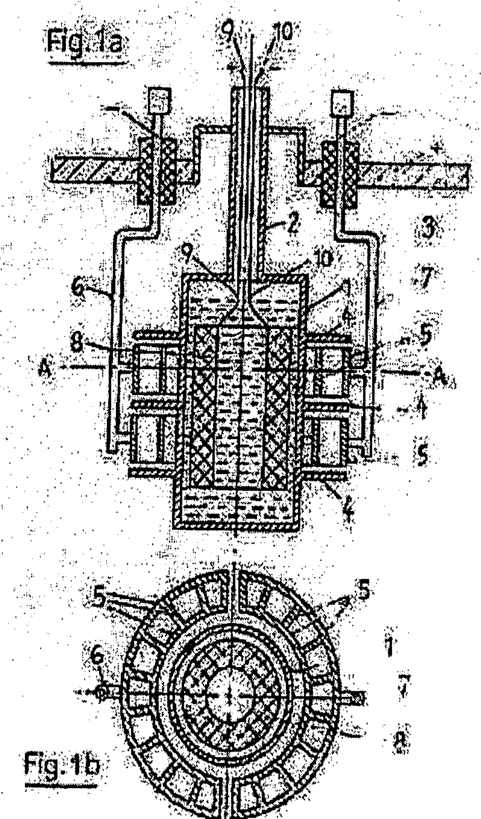


Fig. 1a

Fig. 1b

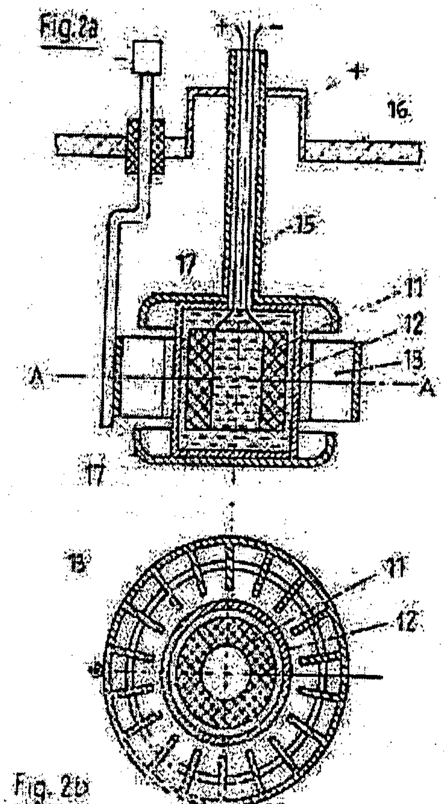
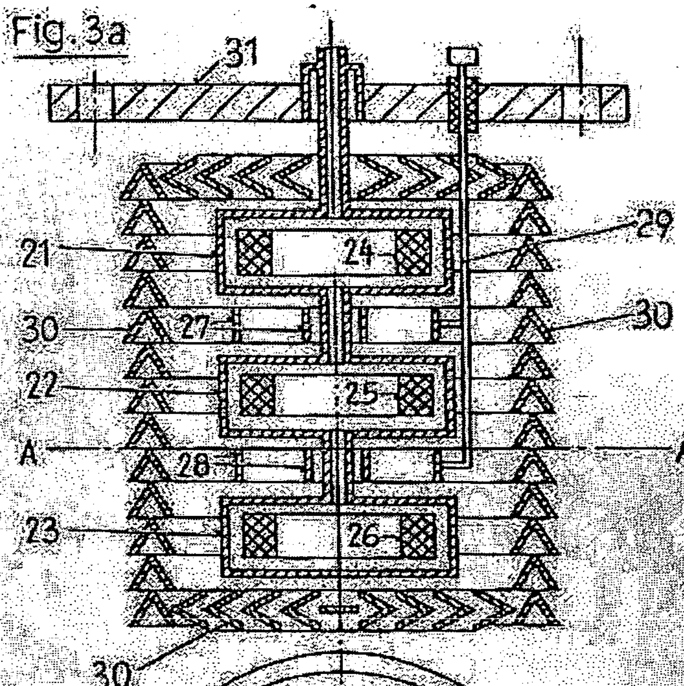


Fig. 2a

Fig. 2b

Fig. 3a



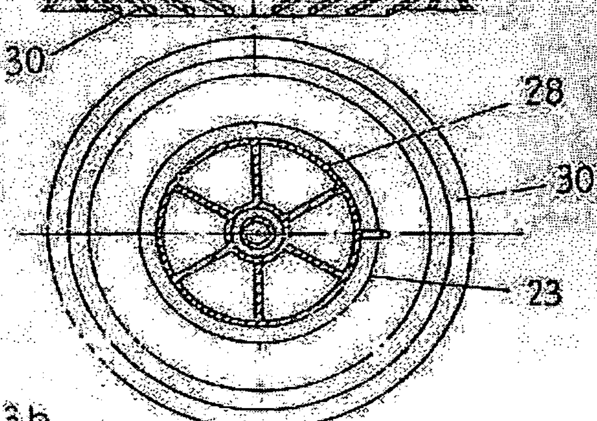


Fig. 3b

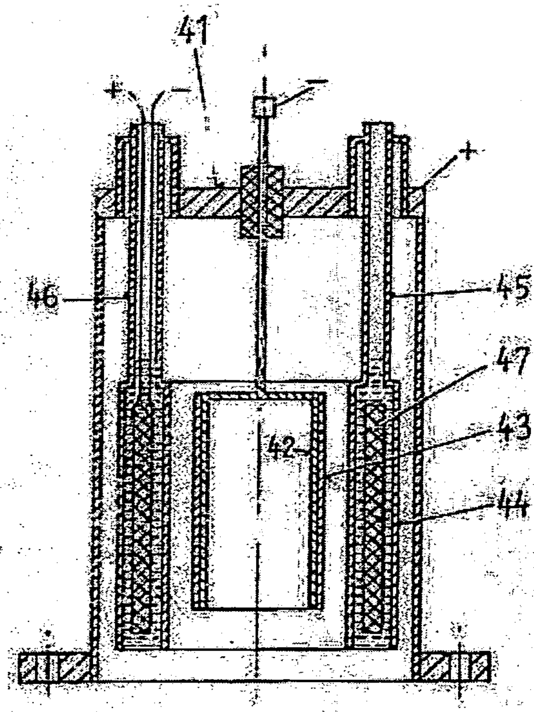


Fig. 4

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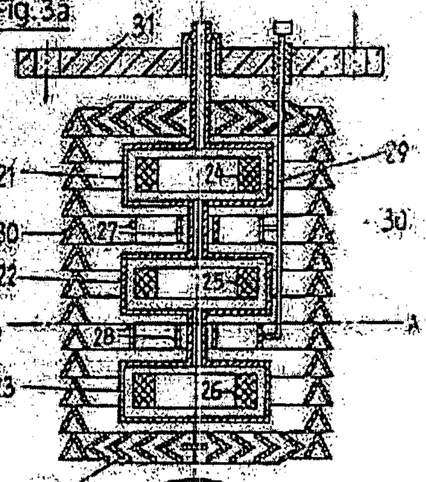
6 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheets 3 & 4

Fig. 3a



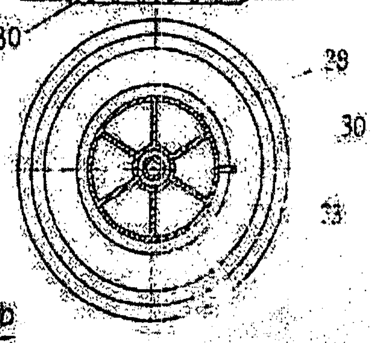


Fig. 3b

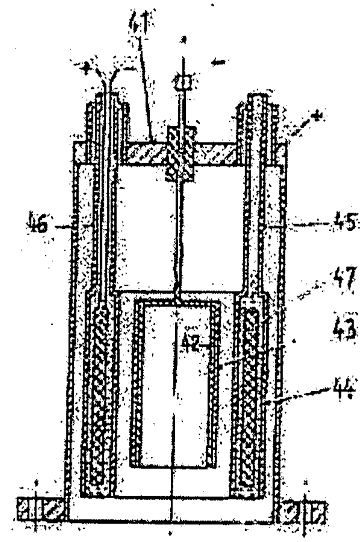


Fig. 4

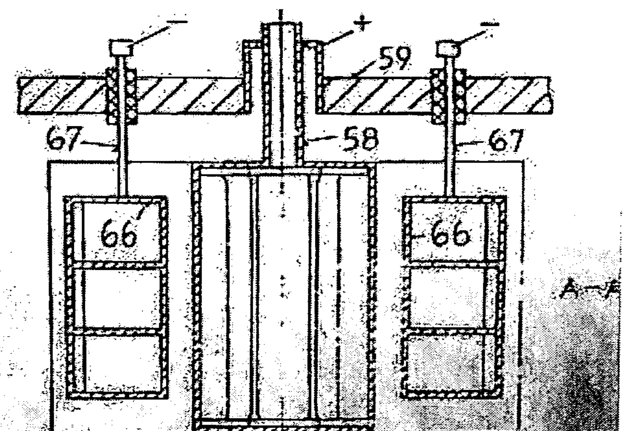


Fig. 5a

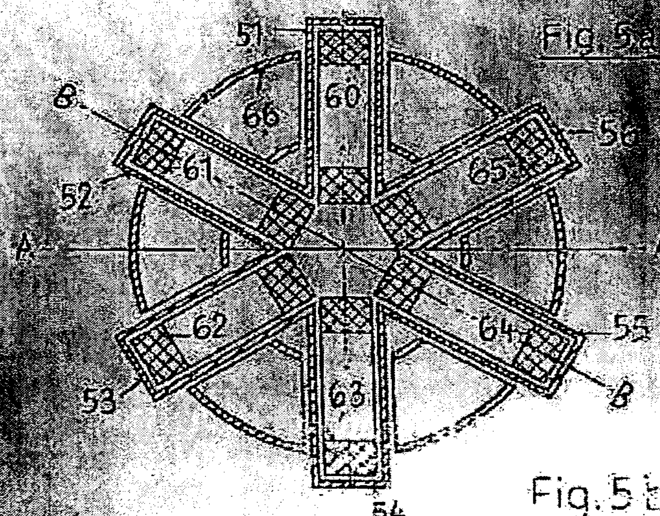


Fig. 5 b

B – B

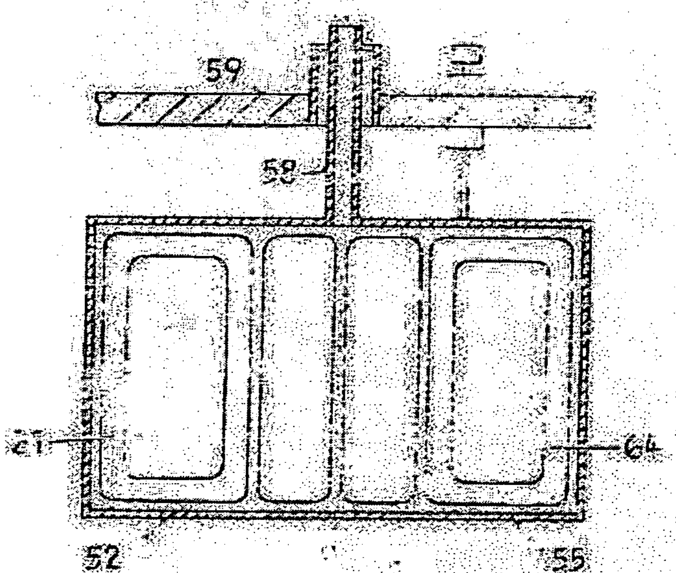


Fig. 5c

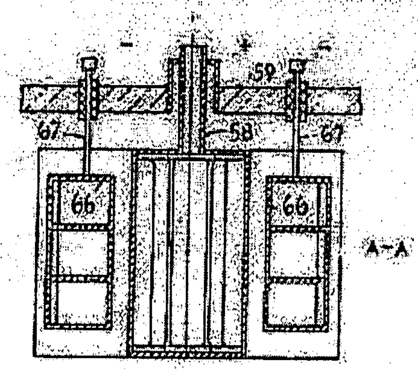


Fig. 5a

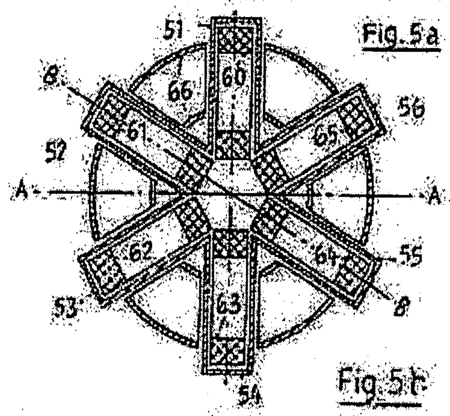


Fig. 5b

B – B

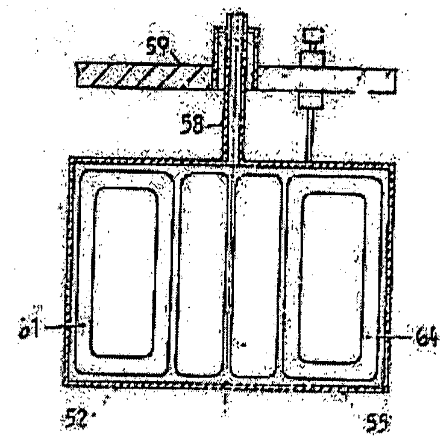


Fig. 5c